DEVELOPMENT AND LIFE DURATION OF THE PINE FEEDING ROOTS

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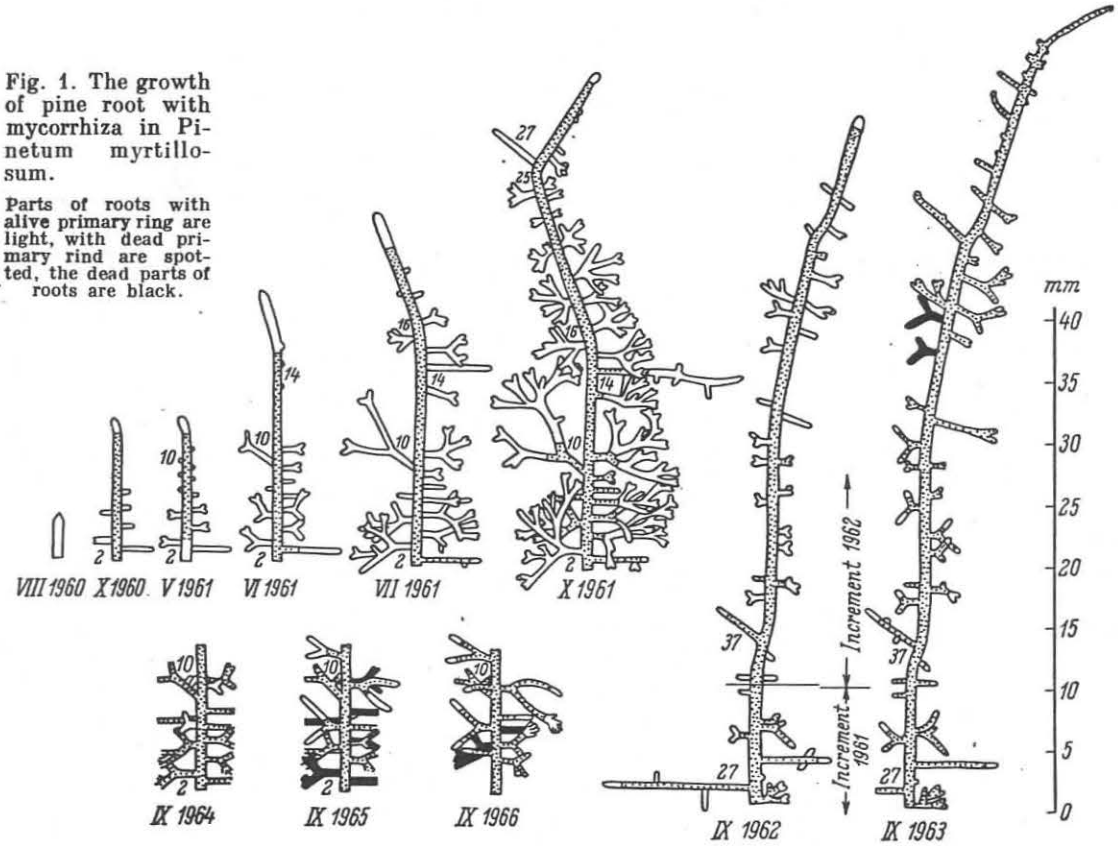
The life cycle of feeding roots is not adequately known even in such well studied species as pine (*Pinus silvestris*); the data on their life duration are very contradictory (Hatch, 1937; Heikurainen, 1957; Rakhteenko, 1962). Therefore, a research was started in 1958 with a view of studying the full life cycle of feeding and of the fine roots of pine in the natural forest. About 20 small fine long roots and more than 100 feeding roots were systematically measured after the techniques stated previously (Orlov, 1957).

The development of one of the long roots and the formation of feeding ones on it in litter of the 50 year old Pinetum myrtillosum are demonstrated in the Fig. 1. Root growth conditions are rather favourable: the roots are always adequately supplied with oxygen, mechanical root growth obstacles being absent, moisture deficiency is seldom.

The root appeared on a thicker long root at the beginning of August 1960. It belonged to the category of the finest (the diameter 0.6—1.0 mm) long roots, on which the bulk of feeding roots is formed. The root grew rather vigorously during warm periods of 1961 and 1962. In spring 1963 despite of quite favourable conditions, the rate of its growth was markedly decreased. In July, as a result of consi-

Fig. 1. The growth of pine root with mycorrhiza in Pinetum myrtillosum.

Parts of roots with alive primary ring are light, with dead primary rind are spotted, the dead parts of roots are black.



derable litter drying, the root top got dry. The next year the whole distal part of the root died off. The basal part had been living for three years more up to the spring of 1967.

The dying off of the distal parts of fine roots is not a general rule. More often the whole root is dying off. However, the decrease of the growth rate in the 3—4th year of the root's life is quite natural.

During the root's growth the feeding roots getting afterwards mycorrhiza were appearing, as well as single fine long roots of the final order, termed by Salyaev (1958) slow growth long roots (Fig. 1). The most-vigorously growing and developing mycorrhiza were formed at the root basis.

The development of some such mycorrhiza is demonstrated in the Figs. 2 and 3; they were indicated by sequence numbers according to their order from the basis of the root. A well-branched mycorrhiza *10* (Figs. 1, 2) has been living for 6 years since the spring of 1961 up to the spring of 1967. The most intensive formation of the suctioning surface on account of the growth of the sprouts and their branching were observed on the 1st and 2nd years of their life (see the Table). In the following years the growth decreased by more than two times and sharply fell down in the last year of life — 1966.

Changes in pine mycorrhiza surface

Mycorrhiza No	Year	Increment per year, mm²	Dying off per year, mm²	Surface		
				tatal, mm²	active, mm²	%
10	1961	49.7	0	48.8	44.0	89
	1962	68.4	0	108.0	42.0	36
	1963	29.8	19.1	111.7	22.1	17
	1964	23.2	0	134.0	31.0	21
	1965	27.6	4.8	152.4	35.4	21
	1966	5.5	32.6	124.0	21.0	15
2	1960	3.1	0	3.1	3.1	100
	1961	47.6	0	49.8	43.3	85
	1962	26.1	0	67.2	6.2	8
	1963	14.1	21.4	57.7	5.1	8
	1964	7.9	7.2	57.8	7.1	11
	1965	0	17.2	39.8	0	0

The dying off of the primary rind on the basal parts of mycorrhiza was observed as early as the end of the first season of life. In the following years the growth of sprouts was followed by a gradual spreading of the zone with the died off rind to the distal parts of the mycorrhiza. Therefore, the integral surface of the parts with alive primary rind was kept up during all years at an approximately similar level; this surface was termed as an ac-

tive one, because the active absorption of nutrients is only possible with the preservation of alive cells in the root surface tissue (Ivanov, 1953). As an exception the active surface was markedly decreased in the dry year of 1963 and on the eve of dying off in 1966 (see the Table). In the summer of 1963 some of the mycorrhiza branches died off (Fig. 2, see the Table). The dying off was renewed in 1965, being especially vigorous in 1966. It is remarkable that the spreading of mycorrhiza was not only a result of the dichoto-

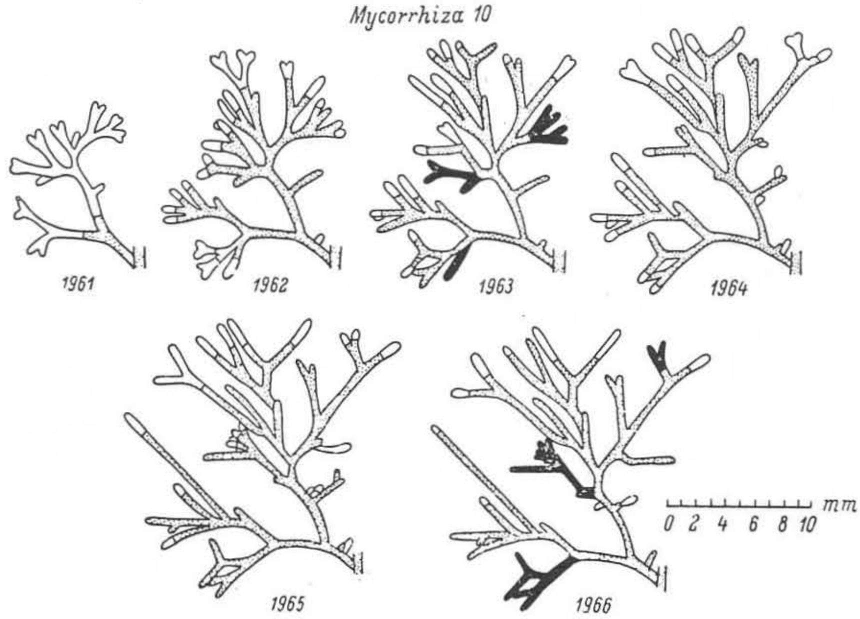


Fig. 2. The growth of pine mycorrhiza.
The legend is similar to that in Fig. 1.

mous branching of growth points but also of the emergence of small sprouts on its old parts.

The development of less branched mycorrhiza *2*, *16* and *25* (Fig. 3) which lived a shorter period — 4—5 years is similar to that of mycorrhiza *10*. The growth of sprouts is either decreasing with age or stopping 1—2 years before the death of mycorrhiza.

Besides the growth of mycorrhiza which were formed near the growing top of the long root, new mycorrhiza emerged on its old part too. Their growth is shown in the lower left part of Fig. 1.[1] The formation and growth of the mycorrhiza of the second generation proved to be more intensive since 1965, when a considerable part

[1] The old mycorrhiza have not been fully presented here.

of old mycorrhiza died off. They were smaller in size than mycorrhiza of the first generation, their branching being poorer and dying off coming sooner.

Fine long and feeding pine roots can live for a long time in conditions of a periodic anaerobiosis caused by submergence with soil waters. A full evaluation of the effect of unfavourable aeration was made earlier (Orlov, 1966). A study of one of the small growth roots in the surface layer of peat of Pinetum myrtilloso-sphagnosum could be given as an example (Fig. 4). Despite of long submergences pe-

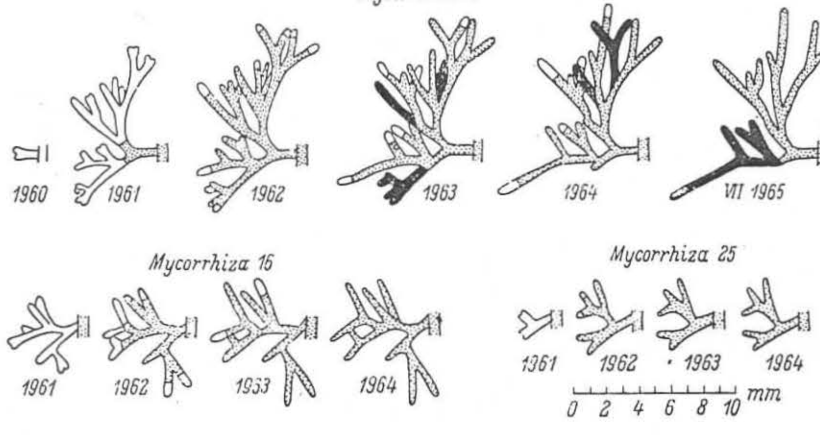


Fig. 3. The growth of pine mycorrhiza.
The legend is similar to that in Fig. 1.

riods during both spring and autumn, and in some years for a short time in summer, the root lived for 8 years — since July 1958 to May 1966. In very moist years (i. e. 1962) a considerable part of young feeding roots (unbranched and forked mycorrhiza) died off, being replaced by new ones in the following years. Some feeding roots, as could be seen in Fig. 4, lived for 8 years. The long root was growing vigorously in the first two years only. However, a slow elongation of the root top has been occurring until the last year of its life.

The results of our investigations give ground to believe that the absorbing root system of pine exists for a long time being slowly replaced by a new one. The average longevity of fine long roots is about 6—7, sometimes more than 8 years. The mean lifetime of mycorrhiza is about 4, the maximum — 8 years. The increment of the young mycorrhiza active surface is followed by a gradual spreading of the zone with the died off rind from the base up to the distal

parts. Therefore, the alive primary rind is usually existing during one vegetation period. In other cases it lives either during a part of the vegetation period or, on the contrary, the period of its existence increases up to two years.

The peculiarities in formation of distal parts of pine roots show that the expansion of pine feeding roots into the soil proceeds very slowly. Fine long roots and mycorrhiza developed on them grow more

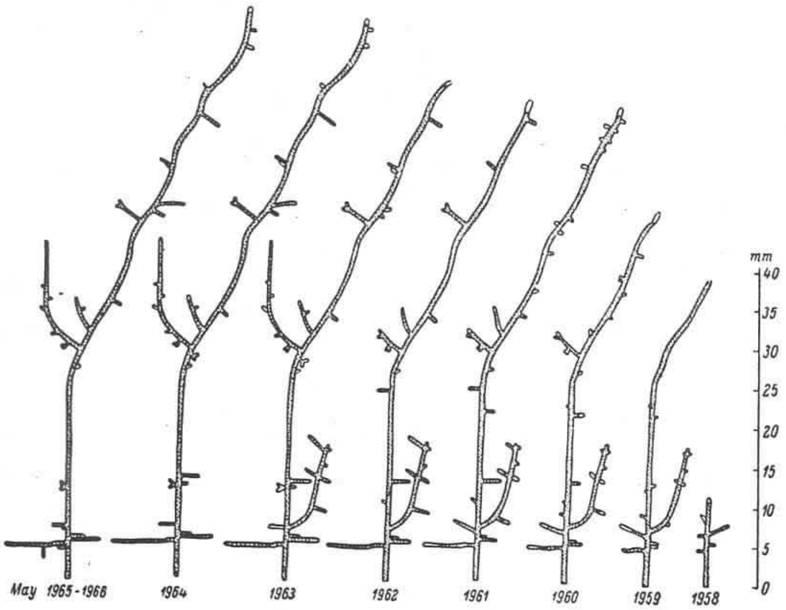


Fig. 4. The growth of pine root with mycorrhiza in Pinetum myrtilloso-sphagnosum.

The legend is similar to that in Fig. 1.

or less fast for not more than 1—2 years. Further expansion of their activity area is quite limited, as the increment of long roots usually is limited at the rate of a few centimeters; the increment in the length of mycorrhiza distal parts being a few millimeters a year. The system of a long root with mycorrhiza makes use of the same soil volume for several years.

The conclusion of a comparatively slow expansion of pine long roots into the soil may be confirmed in a different way as well. The annual mass increment of feeding pine roots in different types of Pinetum in taiga zone fluctuates within 180—270 kg/ha (Orlov, 1967).

The ratio between the dry weight and the surface of feeding roots with alive primary rind was about 54 mm²/mg; this ratio was cal-

culated by measuring of their longitudes and diameters in the sample. Therefore, the annual increment in the feeding roots surface was about 10—15 thousand m^2 per 1 ha. This value which is near to the area of the plot can hardly be considered high enough, taking into account the fact that the supply of nutrients to the root surface is known to be only possible from a comparatively small space around the root.

Kalela (1954) reports that 100 years old pine possessed 5 mln root tops. If the mean length of the root top is to be taken as 4 mm, its diameter being 0.5 mm, the surface of pine root tops will constitute only 30 m^2. With the 500 trees per 1 ha of 100 years old stand, the integral of root tops surface will be 15 thousand m^2 per 1 ha. This value is of the same order as the one obtained by us.

The results of our investigations are out of keeping with the well-known notion that a vigorous and permanent expansion of roots into the soil and a great length of roots are necessary for a successful supply of roots with nutrients and water (Maksimov, 1953; Kramer and Kozlovsky, 1963).

The very fact of the great length of root system of trees (Kramer and Kozlovsky, 1963) is not surprising but that of the insignificance of the feeding surface of the pine and possibly, other species' roots, which do not possess hairs, is doubtful. The mechanisms of supply of the tree with water and nutrients by means of feeding surface equal approximately the area of the plot, which is occupied by the tree, calls for further investigation.

These findings appear to be in agreement with published statement about the great role of fungi which form mycorrhiza in the increasing the feeding surface of mycotroph species' roots.

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